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(56) Documents Cited
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US 5027090 A   US 5008640 A

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(54) Support arrangement for a dielectric element within a cavity, for a dieletric resonator filter

(57) A dielectric resonator filter including at least one microwave resonator having a cylindrical conductive cavity (1) symmetrically disposed about a longitudinal axis and an internally projecting flange (3); a cylindrical dielectric resonator element(4); and a ceramic support member (5) for the resonator element (4), the support member (5) having a coefficient of thermal expansion to match that of the resonator element (4) and being secured to the said internally projecting flange (3) and adapted to support the resonator element (4) in a spacial central position within the cavity whereby the longitudinal axes of the cavity (1) and the resonator element (4) are coaxial. The support member (5) is in the form of a ceramic disc having a central aperture within which the dielectric resonator is securely located at the periphery thereof, the shape of the aperture being such that the resonator element is secured to the support member at its low azimuthal field positions of the HEH$_{11\delta}$ mode. The filter may be stacked to form a plurality of cascaded dielectric filters for use as a demultiplexer in a satellite communication system.
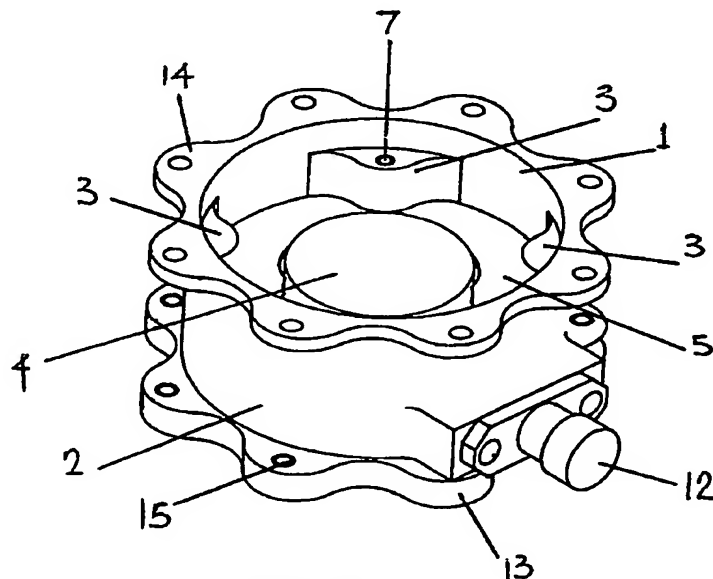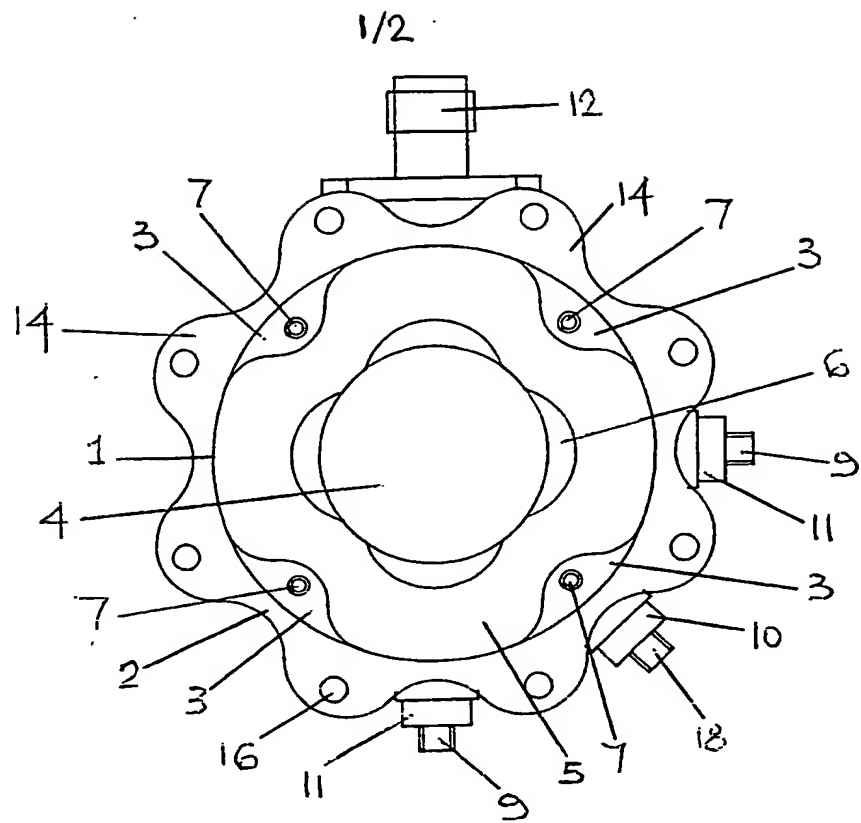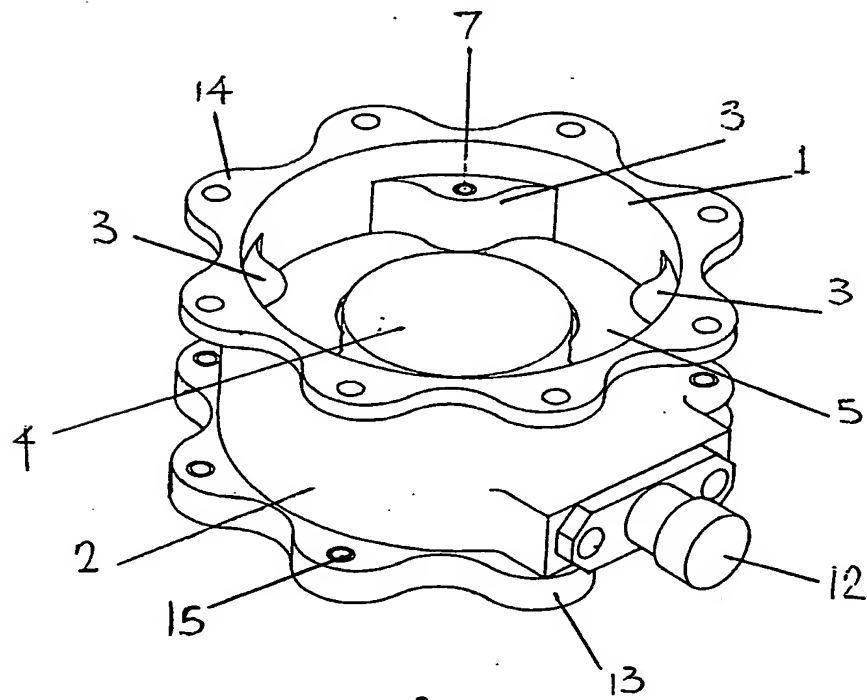
FIGURE 3

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FIGURE 1

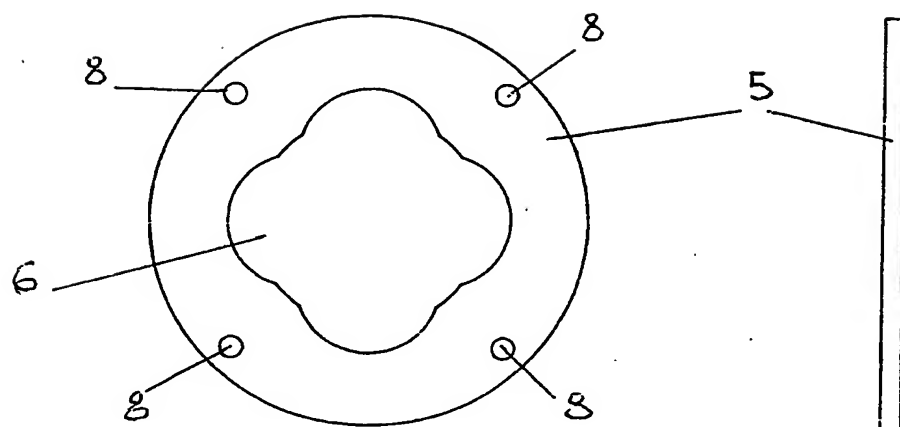
FIGURE 3

8

8

5

6

8

8

FIGURE 2

DIELECTRIC RESONATOR FILTER

The invention relates to a dielectric resonator filter having, a particular, but not necessarily an exclusive, application in a dual mode filter for communications satellite payloads.

With communications satellite payloads, the main problem encountered in realising practical dielectric resonator filters is in supporting the dielectric resonator in a spatial central position within the cavity of the filter.

Ideally, the dielectric resonator should hang in free space but, in practice, it is necessary to provide a support structure for the resonator within the cavity. The support structures of known dielectric resonator filters degrade the unloaded electrical quality factor of the resonator. This is due to additional losses induced in the fabric of the support structure.

The resonator support structures used in dielectric resonator filters for communications satellite payloads must be sufficiently rugged and stable to withstand both the high

levels of vibration experienced by space hardware during the launch phase of a mission and also the long term effects of repeated thermal cycling experienced over the duration of the mission.

In addition, the perturbation of the resonators electrical performance must be minimised and, in particular, all additional electrical losses, given rise to by the resonator support structure, must be minimised in order to achieve the extremely high levels of unloaded Q required by narrow band filters.

It is an object of the present invention to overcome the foregoing problems by providing a dielectric resonator filter having a support structure for the dielectric resonator which has a high mechanical ruggedness, minimises thermally induced stress and has low electrical loss.

The thermally induced stress is minimised by closely matching the thermal expansion coefficients of all of the materials from which the filter and support structure are fabricated.

The low electrical loss is due to low loss tangents, low dielectric filling factors and the positioning of the

support member within the cavity of the resonator so as to avoid areas of high electric field concentration.

The invention provides a dielectric resonator filter including at least one microwave resonator having a cylindrical conductive cavity symmetrically disposed about a longitudinal axis, and an internally projecting flange; a cylindrical dielectric resonator element; and a ceramic support member for the resonator element, the support member having a coefficient of thermal expansion to match that of the resonator element and being secured to the said internally projecting flange and adapted to support the resonator element in a spacial central position within the cavity whereby the longitudinal axes of the cavity and the resonator element are coaxial.

The said internally projecting flange is preferably formed as an integral part of the cavity and consists of four equi-spaced lugs to which the support member is secured, the lugs being located at the low azimuthal field positions of the $HEH_{11\delta}$ mode of the dielectric resonator.

The support member can be releasably secured to the equi-spaced lugs by either silver plated bolts, or silver soldering.

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The support member can be secured to the resonator element either by ceramic bonding, or by low loss adhesive.

According to one aspect of the present invention the support member is in the form of a ceramic disc having a central aperture within which the dielectric resonator is securely located at the periphery thereof, the shape of the aperture being such that the resonator element is secured to the support member at its low azimuthal field positions of the HEH_{116} mode. In a preferred arrangement the thickness of the ceramic disc is less than one third of the length of the cylindrical dielectric resonator element.

The support member is preferably of a ceramic material, for example, a glass ceramic material, having high stability and ruggedness, and low permitivity and loss tangent, and be such that its electrical, mechanical and thermal expansion properties can be optimised during fabrication.

According to another aspect of the present invention the coefficient of thermal expansion of the conductive cavity is matched to that of the ceramic support member.

According to a further aspect of the present invention, the surface of the ceramic support member at or near the periphery thereof is metallised, and the metallised surface is secured to the internally projecting flange of the cavity. The securing of the support member to the internally projecting flange can be effected by either brasing or silver soldering, the joint formed thereby being of high ruggedness and low loss.

According to a further feature of the present invention, the cylindrical conductive cavity can be fabricated from either silver plated beryllium metal or silver plated titanium, the dielectric resonator element having a coefficient of thermal expansion to match that of the beryllium or the titanium, as the case may be.

According to a further feature of the present invention, the cylindrical conductive cavity is of a nickel/iron alloy, the coefficient of thermal expansion of the cavity being matched to that of the dielectric resonator by varying the nickel content of the alloy.

The foregoing and other features according to the present invention will be better understood from the following description with reference to the accompanying

drawings, in which:-

Figure 1 illustrates, in a front view, a dielectric resonator cavity for a dielectric resonator filter according to the present invention,

Figure 2 illustrates, in a front view and side elevation, a ceramic support member for supporting the dielectric resonator in the cavity illustrated in Figure 1 of the drawings, and

Figure 3 illustrates, in a pictorial view, the dielectric resonator cavity illustrated in Figure 1 of the drawings.

The dielectric resonator according to the present invention includes at least one dielectric resonator cavity which is constructed, in a preferred arrangement, in the manner illustrated in Figures 1 and 3 of the accompanying drawings.

As illustrated in Figures 2 and 3, the resonant cavity 1 is formed in a housing member 2 having an internally projecting flange formed by four equi-spaced lugs 3. The cylindrical cavity 1 is symmetrically disposed about the

longitudinal axis of the housing member 2. In a preferred arrangement, the internally projecting flange is formed integrally with the housing member 2.

A cylindrical dielectric resonator 4 is centrally located within the cylindrical cavity 1 by means of a ceramic support member 5. The longitudinal axes of the cavity 1 and resonator 4 are coaxial.

In a preferred arrangement, the resonator 4 is located at the longitudinal centre of the cavity 1 by the support member 5, i.e. the longitudinal centres of the resonator 4 and cavity 1 are coincident.

The housing member 2 is fabricated from a metal having a coefficient of thermal expansion matched to that of the resonator 4 and support member 5. Examples of metals from which the housing member 2 can be fabricated are titanium, beryllium and a nickel/iron alloy. In particular, silver plated beryllium metal or silver plated titanium. The coefficient of thermal expansion of the nickel/iron alloy can be varied in a controllable manner by varying the nickel content of the alloy. Thus, the coefficient of thermal expansion of a nickel/iron alloy housing member 2 can be readily matched to that of the ceramic resonator element 4.

The choice of material for the housing member 2 is dependent on the ceramic material used for resonator 4 and support member 5.

The silver plated beryllium which has a coefficient of thermal expansion that is very closely matched to the typical coefficients of thermal expansion for microwave dielectric resonator ceramics, is particularly suitable for dielectric resonator filters adapted for operation at lower frequencies i.e. of the order of 4GHz or less, where the diameter of the dielectric resonator filter begins to exceed 30mm.

Similarly, silver plated titanium is, for the foregoing reason, also an ideal material for the housing member 2, but the higher density of titanium in comparison to beryllium makes it more suitable for dielectric resonator filters operating at frequencies of the order of 12GHz.

As illustrated in a front view and side elevation in Figure 2 of the drawings, the ceramic support member is in the form of a single planar disc having a central aperture 6 formed therein within which the dielectric resonator 4 is centrally located, as is illustrated in Figures 1 and 3.

As can be seen from the drawings, the equatorial
planes of the dielectric resonator 4 and the ceramic support
member 5 are coincident.

The shape of the aperture 6 in the support member 5
which is the characteristic clover leaf shape, is such that
the dielectric resonator 4 is, as is best illustrated in
Figure 1 of the drawings, secured at four equi-spaced points
on the periphery of the cylindrical resonator. In operation
of the cavity, these four points are the low azimuthal field
positions of the $HEH_{11\delta}$ mode of the dielectric resonator 4.

Thus, the clover leaf shape of the aperture 6 results
in the removal of those sections of the support member 5
that are in the high field locations of the $HEH_{11\delta}$ mode as
viewed, as in Figure 1 of the drawings, from the end face of
the resonator. This maximises field confinement and
minimises dielectric losses.

In practice, the support member 5 is of a thickness
less than the length of the cylindrical resonator 4 and is
suitably secured to the four points on the periphery of the
resonator 4 within the length of the resonator, i.e. it
must not extend beyond either of the end faces of the
resonator 4. In a preferred arrangement, the thickness of

the support member 5 is less than one third of the length of the cylindrical dielectric resonator 4 in order to minimise the amount of support dielectric within the cavity and to thereby minimise the "filling factor".

The support member 5 is of a ceramic material having high stability and ruggedness, and low permitivity and loss tangent. Furthermore, the ceramic material must be such that the electrical, mechanical and thermal expansion properties of the support member 5 can be optimised during fabrication. In particular, the ability to optimise the coefficient of thermal expansion to match that of the dielectric resonator 4 is of particular importance because of the need to minimise thermally induced stresses.

If the thermally induced stresses are not minimised, then this would compromise survivability of the resonator over extended lifetimes of typically ten years.

The use of glass ceramic materials, such as cordierite, enstatite, or forsterite, for the support member 5 are preferred. With such materials, the support member 5 can be made from a single sheet of glass ceramic which is laser cut to the shape illustrated in Figure 2 of the drawings.

Glass ceramics also have high Weibel moduli so that support strength is predictable and hence design margins are smaller and reliability is more predictable.

The bonding mechanism for securing the support member 5 to the lugs 3 of the internally projecting flange and to the periphery of the dielectric resonator 4 can be any suitable arrangement which provides highly rugged and low loss joints and which, for some application, allows removal of the support member 5 from the cavity to be effected, i.e. the support member 5 is releasably secured to the lugs 3.

As stated above, the material of the support member 5 is engineered to have a coefficient of thermal expansion matched to that of the dielectric resonator 4. The coefficient of thermal expansion of glass ceramic materials is variable and is a function of the ceramic used, the quantities and types of additives and the processing parameters.

As illustrated in the accompanying drawings, a surface of the support member 5 at or near the periphery thereof lies against the inside face of the flange. This surface is metallised and secured to each of the lugs 3 either by

brasing or soldering, for example, silver soldering. The joints formed between the support member 5 and the lugs 3 of the internally projecting flange are highly rugged, require no adhesives and are, therefore, low loss. In the case of soldering the support member could, if desired, be readily removed from the cavity by reheating of the solder joint.

The metallisation of the support member 5 can be effected by the application of metal ink to the required areas of the support member 5 and co-firing the support member 4 and metal ink at a high temperature, for example, in the range 400°C to 800°C.

As is illustrated in Figures 1 and 3 of the drawings, the support member 5 can be releasably secured to the four lugs 3 to form low loss joints by the use of silver plated bolts and washers of a low loss material. With this arrangement, a screw threaded hole 7 is provided in each of the lugs 3 and the support member 5 is, as illustrated in Figure 2, provided with four holes 8 corresponding to the screw-threaded holes 7. The support member 5 is secured to the lugs 3 by silver plated bolts with a washer of low loss material positioned between the head of the bolt and the support member 5.

This arrangement for securing the support member 5 in position is ideally suited for dielectric resonator filters operating at frequencies of the order of 4GHz.

The securing of the support member 5 to the periphery of the dielectric resonator 4 can be effected by the application of suitable low loss adhesives but for those structures in which the coefficients of thermal expansion for the support member 5 and dielectric resonator 4 are matched to within 1.0ppm/°C, ceramic bonding can be used. This involves the positioning of a piece of green state ceramic between the periphery of the resonator 4 and each of the four forks of the shaped aperture 6 in the support member 5. The assembly is then fired in a known manner to produce a continuous ceramic bond between the support member 5 and resonator 4 at each of the contact points. These bonds are both very strong and very low loss due to the absence of adhesives.

As illustrated in Figure 1 of the drawings, the dielectric resonator filter includes a coupling screw 8 which extends into the cavity 1 on a radial plane that is at 45° to the two orthogonal dual mode electrical field orientations of the cavity 1 i.e. in alignment with one of the lugs 3. The filter also includes two resonance tuning

screws 9 each one of which extends into the cavity 1 on a radial plane coincident with a respective one of the two orthogonal mode electrical field orientations.

The screw-threaded holes that are provided in the housing member 2 for the screws 8 and 9 enable the position of the screws to be adjusted, i.e. the extent to which the screws 8 and 9 extend into the cavity is adjustable. As, and when, a desired position is reached the screws 8 and 9 are respectively locked in position by locking nuts 10 and 11.

A coaxial input connector 12 for the cavity 1 is illustrated in Figures 1 and 3 of the drawings.

In practice, the dielectric resonator filter includes a plurality of the dielectric resonators illustrated in Figures 1 and 3 of drawings connected in cascade with resonant energy coupling means interposed between each pair of adjacent dielectric resonators. The housing member 2 is provided with flanges 13 and 14 to facilitate the cascaded couplings. The flange 13 is provided with a number of through nodes 15 and the flange 14 is provided with a matching number of screw-threaded holes 16. The holes 15 and 16 being in alignment when the flange 13 of one cavity

is aligned with the flange 14 of an adjacent cavity. The adjacent cavities are connected together by bolts, each one of which passes through a respective one of the holes 16 and into the corresponding screw-threaded hole 15. The resonant energy coupling means referred to above which, in practice, is in the form of a planar member with a coupling iris formed therein, for example, a cruciform shaped aperture, would be interposed between the flanges 13 and 14, and provided with a number of through holes in alignment with the holes 15 and 16.

A dielectric resonator filter including a plurality of cascaded dielectric resonators of the type outlined in the preceding paragraphs with reference to the accompanying drawings, is ideally suited for use as a multiplexer and/or a demultiplexer.

CLAIMS

1.   A dielectric resonator filter including at least one microwave resonator having a cylindrical conductive cavity symmetrically disposed about a longitudinal axis and an internally projecting flange; a cylindrical dielectric resonator element; and a ceramic support member for the resonator element, the support member having a coefficient of thermal expansion to match that of the resonator element and being secured to the said internally projecting flange and adapted to support the resonator element in a spacial central position within the cavity whereby the longitudinal axes of the cavity and the resonator element are coaxial.

2.   A dielectric resonator filter as claimed in claim 1 wherein the support member is in the form of a ceramic disc having a central aperture within which the dielectric resonator is securely located at the periphery thereof, the shape of the aperture being such that the resonator element is secured to the support member at its low azimuthal field positions of the $HEH_{11\delta}$ mode.

3.   A dielectric resonator filter as claimed in claim 2 wherein the thickness of the ceramic disc is less than one

third of the length of the cylindrical dielectric resonator
element.

4. A dielectric resonator filter as claimed in any
one of the preceding claims wherein the support member is of
a ceramic material having high stability and ruggedness, and
low permitivity and loss tangent, and wherein the
electrical, mechanical and thermal expansion properties of
the support member can be optimised during fabrication.

5. A dielectric resonator filter as claimed in claim
4 wherein the ceramic support member is fabricated from a
glass ceramic material.

6. A dielectric resonator filter as claimed in any
one of the preceding claims wherein the coefficient of
thermal expansion of the conductive cavity is matched to
that of the ceramic support member.

7. A dielectric resonator filter as claimed in any
one of the preceding claims wherein the surface of the
ceramic support member at or near the periphery thereof is
metallised and wherein the metallised surface of the support
member is secured to the said internally projecting flange.

8.   A dielectric resonator filter as claimed in claim 7 wherein the support member is secured to the said internally projecting flange by either brasing or silver soldering, and wherein the joint formed thereby is of high ruggedness and low loss.

9.   A dielectric resonator filter as claimed in any one of the preceding claims wherein the cylindrical conductive cavity is of silver plated beryllium metal, the dielectric resonator element having a coefficient of thermal expansion to match that of the beryllium.

10.   A dielectric resonator filter as claimed in any one of the claims 1 to 8 wherein the cylindrical conductive cavity is of silver plated titanium, the dielectric resonator element having a coefficient of thermal expansion to match that of the titanium.

11.   A dielectric resonator filter as claimed in any one of claims 1 to 8 wherein the cylindrical conductive cavity is of a nickel/iron alloy, the coefficient of thermal expansion of the cavity being matched to that of the dielectric resonator by varying the nickel content of the alloy.

12.   A dielectric resonator filter as claimed in   any
one of the preceding claims wherein the said internally
projecting flange is formed as an integral part of the
cavity and consists of four equi-spaced lugs, and wherein
the lugs are located at the low azimuthal field positions of
the $HEH_{II\delta}$ mode of the dielectric resonator.

13.   A dielectric resonator filter as claimed in   any
one of the preceding claims wherein the resonator element is
located   at   the   longitudinal   centre   of   the   cylindrical
conductive cavity.

14.   A dielectric resonator filter as claimed in   any
one of the claims 1 to 6 wherein the said internally
projecting flange is formed as an integral part of the
cavity and consists of four equi-spaced lugs, wherein the
lugs are located at the low azimuthal field positions of the
$HEH_{II\delta}$ mode of the dielectric resonator, and wherein the
support member is releasably secured to the four lugs to
form low loss joints between the support member and the
lugs.

15. A dielectric resonator filter as claimed in claim
14 wherein a screw-threaded hole is provided in each of the
lugs, wherein the support member has holes formed therein

corresponding to the screw-threaded holes in the lugs and wherein the support member is secured to the lugs by silver plated bolts, a washer of a low loss material being positioned between the head of each of the bolt and the support member.

16. A dielectric resonator filter as claimed in any one of the claims 2 to 15, wherein the coefficients of thermal expansion of the dielectric resonator and the ceramic support member are matched to within 1.0ppm/°C, and wherein the dielectric resonator is secured to the ceramic support member at four points on the periphery thereof by means of a low loss ceramic bound produced by a firing process.

17. A dielectric resonator filter as claimed in any one of the preceding claims including a coupling screw which extends into the cavity on a radial plane that is at 45° to the two orthogonal dual mode electrical field orientations of the cavity and at least two resonance tuning screws each one of which extends into the cavity on a radial plane coincident with a respective one of the said two orthogonal dual mode electrical field orientations, the extent to which the coupling and tuning screws extend into the cavity being adjustable.

18. A dielectric resonator filter as claimed in any one of the preceding claims including a plurality of cascaded dielectric resonators, and resonant energy coupling means interposed between each pair of adjacent dielectric resonators.

19. A dielectric resonator filter as claimed in any one of the preceding claims wherein the ceramic support member is of cordierite, or enstatite, or forsterite.

20. A dielectric resonator filter substantially as hereinbefore described with reference to the accompanying drawings.

21. A multiplexer/demultiplexer including a dielectric resonator filter as claimed in any one of the preceding claims.

22. A communication satellite payload including a demultiplexer as claimed in claim 21.

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Amendments to the claims have been filed as follows

1. A dielectric resonator filter including at least one microwave resonator having a cylindrical conductive cavity symmetrically disposed about a longitudinal axis and an internally projecting flange; a cylindrical dielectric resonator element; and a unitary dielectric support member for the resonator element, the support member having a coefficient of thermal expansion to match that of the resonator element and being secured to the said internally projecting flange and adapted to support the resonator element, at the peripheral surface thereof, in a spacial central position within the cavity whereby the longitudinal axes of the cavity and the resonator element are coaxial.

2. A dielectric resonator filter as claimed in claim 1 wherein the support member is in the form of a ceramic disc having a central aperture within which the dielectric resonator element is securely located at the periphery thereof, the shape of the aperture being such that the resonator element is secured to the support member at its low azimuthal field positions of the $HEH_{11\delta}$ mode.

3. A dielectric resonator filter as claimed in claim 2 wherein the thickness of the ceramic disc is less than one third of the length of the cylindrical dielectric resonator element.

4. A dielectric resonator filter as claimed in any one of the preceding claims wherein the support member is of a ceramic material having high stability and ruggedness, and low permitivity and loss tangent, and wherein the electrical, mechanical and thermal expansion properties of the support member can be optimised during fabrication.

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5.   A dielectric resonator filter as claimed in claim 4 wherein the ceramic support member is fabricated from a glass ceramic material.

6.   A dielectric resonator filter as claimed in any one of the preceding claims wherein the coefficient of thermal expansion of the conductive cavity is matched to that of the dielectric support member.

7.   A dielectric resonator filter as claimed in any one of the claims 1 to 5 wherein the coefficient of thermal expansion of the conductive cavity is matched to that of the dielectric support member and the dielectric resonator element.

8.   A dielectric resonator filter as claimed in any one of the preceding claims wherein the surface of the ceramic support member at or near the periphery thereof is metallised and wherein the metallised surface of the support member is secured to the said internally projecting flange.

9.   A dielectric resonator filter as claimed in claim 8 wherein the support member is secured to the said internally projecting flange by either brasing or silver soldering, and wherein the joint formed thereby is of high ruggedness and low loss.

10.   A dielectric resonator filter as claimed in any one of the preceding claims wherein the cylindrical conductive cavity is of silver plated beryllium metal, the dielectric resonator element having a coefficient of thermal expansion to match that of the beryllium.

11.   A dielectric resonator filter as claimed in any one of the claims 1 to 9 wherein the cylindrical conductive cavity is of silver plated titanium, the dielectric resonator element having a coefficient of thermal expansion to match that of the titanium.

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12. A dielectric resonator filter as claimed in any one of claims 1 to 9 wherein the cylindrical conductive cavity is of a nickel/iron alloy, the coefficient of thermal expansion of the cavity being matched to that of the dielectric resonator element by varying the nickel content of the alloy.

13. A dielectric resonator filter as claimed in any one of the preceding claims wherein the said internally projecting flange is formed as an integral part of the cavity and consists of four equi-spaced lugs, and wherein the lugs are located at the low azimuthal field positions of the $HEH_{11\delta}$ mode of the dielectric resonator element.

14. A dielectric resonator filter as claimed in any one of the preceding claims wherein the resonator element is located at the longitudinal centre of the cylindrical conductive cavity.

15. A dielectric resonator filter as claimed in any one of the claims 1 to 6 wherein the said internally projecting flange is formed as an integral part of the cavity and consists of four equi-spaced lugs, wherein the lugs are located at the low azimuthal field positions of the $HEH_{11\delta}$ mode of the dielectric resonator, and wherein the support member is releasably secured to the four lugs to form low loss joints between the support member and the lugs.

16. A dielectric resonator filter as claimed in claim 15 wherein a screw-threaded hole is provided in each of the lugs, wherein the support member has holes formed therein corresponding to the screw-threaded holes in the lugs and wherein the support member is secured to the lugs by silver plated bolts, a washer of a low loss material being interposed between the head of each of the bolts and the support member.

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17.   A dielectric resonator filter as claimed in any one of the claims 2 to 16, wherein the coefficients of thermal expansion of the dielectric resonator element and the ceramic support member are matched to within 1.0ppm/°C, and wherein the dielectric resonator element is secured to the ceramic support member at four points on the periphery thereof by means of a low loss ceramic bond produced by a firing process.

18.   A dielectric resonator filter as claimed in any one of the preceding claims including a coupling screw which extends into the cavity on a radial plane that is at 45° to the two orthogonal dual mode electrical field orientations of the cavity and at least two resonance tuning screws each one of which extends into the cavity on a radial plane coincident with a respective one of the said two orthogonal dual mode electrical field orientations, the extent to which the coupling and tuning screws extend into the cavity being adjustable.

19.   A dielectric resonator filter as claimed in any one of the preceding claims including a plurality of cascaded dielectric resonators, and resonant energy coupling means interposed between each pair of adjacent dielectric resonators.

20.   A dielectric resonator filter as claimed in any one of the preceding claims wherein the ceramic support member is of cordierite, or enstatite, or forsterite.

21.   A dielectric resonator filter substantially as hereinbefore described with reference to the accompanying drawings.

22.   A multiplexer/demultiplexer including a dielectric resonator filter as claimed in any one of the preceding claims.

23.   A communication satellite payload including a demultiplexer as claimed in claim 22.

tents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number	GB 9305073.0

Relevant Technical fields	**Search Examiner**
(i) UK CI (Edition L) H1W (WBA, WBX, WGA, WGP, WGX)	
	J A WATT
(ii) Int CI (Edition 5) H01P	

Databases (see over)	**Date of Search**
(i) UK Patent Office	
(ii) ONLINE DATABASE: WPI	7 JULY 1993

Documents considered relevant following a search in respect of claims   1 TO 22

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
Y	GB 2188788 A (MURATA) – see Figures 1-3 and line 91 page 1 – line 12 page 2	1-5, 13, 17-19, 21, 22 at least
Y	EP 0064799 A1 (FORD AEROSPACE) – see Figure 1 and lines 1-10, page 1	1-5, 13, 17-19, 21, 22 at least
Y	EP 0026086 A1 (WESTERN ELECTRIC) – see Figures 1 and 2	1-5, 13, 17-19, 21, 22 at least
Y	US 5027090 A (ALCATEL) – whole document	1-5, 13, 17-19, 21, 22 at least
Y	US 5008640 A (CSELT) – see Figure 1 and lines 8-10, column 2	1-5, 13, 17-19, 21, 22 at least

Category	Identity of document and relevant passages —27—	Relevant to claim

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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